Arduino Nixie Clock v10

Operating Instructions
&
Construction Manual

Document V0010d

Contact Information

If you want to get in contact with us, please email to:

nixie@protonmail.ch

We'll usually get back to you right away. We can help you with kits or construction.

We also offer discounts for direct purchases, we save the Ebay fees, and share this with you. Contact us for information. Usually this works out as about 10%.

Software

The software is available on GitHub at the address:

https://github.com/isparkes/ArdunixNix6/releases

This board works with Release "Revision 3 boards" under the "Releases" tab.

Troubleshooting

If everything does not work as you expect, please carefully look at the tests in the construction steps, and the troubleshooting tips.

At the end of the manual, there is a troubleshooting section, which goes through some of the common problems.

Description

The Arduino Nixie Clock is a beautiful mix of old and new, resulting in a high accuracy, low power clock which will be a talking point in your home.

The clock has the following features:

- Battery backed, temperature compensated, high accuracy clock. The accuracy is Accuracy ±2ppm from 0°C to +40°C. (Maximum 1 minute per year).
- The battery life should be 3 years in normal use.
- Retains the date and time even when turned off (not just for a few minutes, but for as long as the battery lasts)
- Leap Year Compensation Valid Up to the year 2100
- Based on the Arduino micro-controller: Easy to program an well documented.
- Open source hardware and software. Nothing is hidden in this clock.
- You may modify and load the software
- Low power consumption.
- Anti Cathode Poisoning (ACP) makes sure that the tubes will stay healthy for many years with no intervention from you.
- All settings are stored in non-volatile memory. Once they are set, they are remembered forever, or until you change them again.
- RGB back lighting allows you to set the the color of the back lighting to practically any color you desire.
- Ambient light sensing, with automatic tube dimming, which sets the tube and LED brightness according to the light conditions. The tubes could be disturbing during the night if they are left at full brightness.
- Absolutely silent operation. Some Nixie clocks emit an irritating “buzz” or “hiss” which is especially annoying if you keep the clock in a bedroom.
- Long tube life: The multiplexed display and automatic dimming used in this design extends the life of the tubes indefinitely. Some other designs run the tubes too “hard”, and this causes a rapid degradation in the useful life of the tube.
- Automatic week day or weekend blanking, extends the life of tubes even further.

General

The clock has different modes of operation, which you select using the pushbutton. When you start the clock up th very first time, it will start in “Time Display Mode”. We set it up to be the right time for where the clock is being shipped to, so in the best case you will not even need to set the clock the first time!

The other modes of operation are described in the following sections.

Safety

The voltages produced in the High Voltage circuit can reach peaks of 400V! Take precautions not to electrocute yourself! If you are not sure what this means, please do not use this clock and return it for a full refund.

A shock from the clock high voltage circuit is at least a nasty bite. At worst it can kill you.

We decline any responsibility in the case of injury or death.

REPEAT: If you are not sure, please do not use the clock.

Time Display Mode

Normally, the clock will show the time. To show additional information press the button with a “short” press. Each press cycles through the following information. After 5 seconds, the display will revert to the normal time display.

Mode	Description	Values
Date	**Date.** The current date will be shown.	
Temp	**Temperature.** The current internal temperature inside the clock case will be shown in degrees Celsius. If this goes above 40, you should consider ventilating the case, because the temperature compensation is not able to work at such high voltages, and the clock life may be reduced, and the time may drift.	
Light	**Ambient Light Reading.** This shows the current ambient light reading from the LDR (light dependent resistor). It is a normalized value, and goes between 100 (dark) to 999 (bright). This controls the dimming of the tubes.	100: darkest 999: brightest

Setting Mode

To enter setting mode, press the button for more than 1 second (“medium press”). The “tick” LED will start to flash instead of pulse. The number of consecutive flashes indicates the mode you are in.

Each medium press of more than 1 second will move the setting mode onto the next. When you finish the setting modes, the clock returns to normal time display mode.

To exit the setting mode before going through all the options, press the button for more than 2 seconds (“long press”). The “tick” LED will start to pulse again. Another way of exiting is to cycle through all of the setting options, after which you will return to time mode.

To change a setting, press the button for less than one second, and then release it (“short press”).

Mode	Description	Values
	Time mode. This is the normal mode and displays the time. It is the normal start up mode of the clock. If you do nothing. The clock is in this mode. In this mode a short press cycles through the values given in “Time Display Mode”, but always returns to the standard time display after 5 seconds.	
Time and Date Settings		
	Set minutes. Each short press will advance the minute. The minutes roll over back to 0 ffter reaching 59 minutes. Each time you set the minute, the seconds is reset to 0.	
	Set Hours. Each short press will advance the hour. The hours roll over back to zero after reaching 12 or 24 (depending on the 12/24 hours mode).	
	Set Day. Each short press will advance the day. The day roll over back to one after reaching the maximum number of days in the month.	
	Set Month. Each short press will advance the month. The month roll over back to zero after reaching 12.	
	Set Year. Each short press will advance the year. The year roll over back to 2015 after reaching 2099.	
Basic Settings		
“00” flashing	**12 or 24 hour time.** The hours are displayed in 12 or 24 hour mode.	“1” = 12 hour “0” = 24 hour default: 0
“01” flashing	**Blank leading “0”.** Blank out the leading “0” from single digit hours.	“1” = blank “0” = don't blank default: 0
“02” flashing	**Scroll back.** Use the scroll back (rapid count down) effect when changing from “9” to “0”.	“1” = enable “0” = disable default: 1
“03” flashing	**Date format.** Set the format that the date is displayed in.	“0” = YY.MM.DD “1” = MM.DD.YY “2” = DD.MM.YY default: 2
“04” flashing	**Display blanking.** To preserve the tubes, you can set the display to be blanked.	“0” = Don't blank “1” = Weekends “2” = Week days “3” = Always default: 0
Special Effects Settings		
“05” flashing	**Fade Speed Slower**. Each short press will make the fade speed between digits slower.	Default: 50 Max: 200 Min: 20
“06” flashing	**Fade Speed Faster**. Each short press will make the fade speed between digits faster.	Default: 50 Max: 200 Min: 20
“07” flashing	**Scroll-back Speed Slower.** Each short press will make the “scroll-back” speed slower.	Default: 4 Max: 40 Min: 1
“08”	**Scroll-back Speed Faster.** Each short press will make the “scroll-	Default: 4

flashing	back" speed faster.	Max: 40 Min: 1
Back Light Settings		
"09" flashing	**Back Light Mode.** This sets the mode of the back light. "Fixed" mode will show the back light color according to the Red, Green and Blue channel intensities. "Pulse" will make the intensity of the back light "pulse", brightening for a second and then darkening for a second, but always respecting the relative intensities set by the Red, Green and Blue channel intensities. "Cycle" fades the back lighting randomly, and does not use the Red, Green and Blue channel intensities.	"0" = Fixed "1" = Pulse "2" = Cycle default: 0
"10" flashing	**Red Channel Intensity.** Sets the maximum intensity of the red channel back light. This will be dimmed according to the display dimming.	Default: 15 Max: 15 Min: 0
"11" flashing	**Green Channel Intensity.** Sets the maximum intensity of the green channel back light. This will be dimmed according to the display dimming.	Default: 15 Max: 15 Min: 0
"12" flashing	**Blue Channel Intensity.** Sets the maximum intensity of the blue channel back light. This will be dimmed according to the display dimming.	Default: 15 Max: 15 Min: 0
HV Generation Settings (See "HV Settings" note)		
"13" flashing	**HV Target Voltage Higher.** Each press sets the HV target voltage higher by 5V.	Default: 180 Max: 200 Min: 150
"14" flashing	**HV Target Voltage Lower.** Each press sets the HV target voltage lower by 5V.	Default: 180 Max: 200 Min: 150
"15" flashing	**PWM On Time Longer.** This setting controls how long the PWM On pulse is. Normally you should not have to change this, but you can try changing this is the HV generation is noisy or you have unusual tubes.	Default: 150 Max: 50 Min: 500
"16" flashing	**PWM On Time Shorter.** This setting controls how long the PWM On pulse is. Normally you should not have to change this, but you can try changing this is the HV generation is noisy or you have unusual tubes.	Default: 150 Max: 50 Min: 500
Information Settings		
"17" flashing	**Current case temperature.** Show the current temperature inside the case (used as part of the temperature compensation for the clock crystal).	
"18" flashing	**Clock version.** Show the clock software version.	
	Digit Test. Will roll through all digits on all locations to check that the display is healthy.	

Note "HV Settings": Before leaving the clock for long periods with a new "HV Generation" setting, check that neither the IRF740 MOSFET nor the 7805 voltage regulator is running too hot. If either of these components gets too hot, either adjust the high voltage settings or add a heat sink.

Display Blanking Mode

During display blanking mode the tubes will be off depending on the display blanking settings, but the “back light” LED will continue to work as usual, telling you that the clock is still running.

You can configure the display to blank at weekends, during week days, always or never (the default).

In order to display the time during blanking, just press the button, and the time will be displayed for the rest of the minute.

Tube Healing Mode

After a long period of time, tube filaments which are not often used (e.g. the “9” on the tens of hours or minutes) can get dim, despite the ACP that is regularly done.

If you make a “super-long” press of the button (more than 8 seconds), the clock will enter filament healing mode. All the power will be placed through a single filament of a single digit to clean it. A short press will change the selected filament.

Another super-long press or cycling through all the filaments will return the clock to normal.

Caution! Don't leave a single filament in this state for an extended period of time. It is a harsh process, and may damage the tube if you leave it in this mode for too long. Normally a few minutes will restore the cathode digit.

Factory Reset

To reset the clock back to initial settings, hold down the button while powering on. The “tick” LED will flash 10 times to signal that the reset has been done.

Everything will be reset back to the factory default state.

External power supply

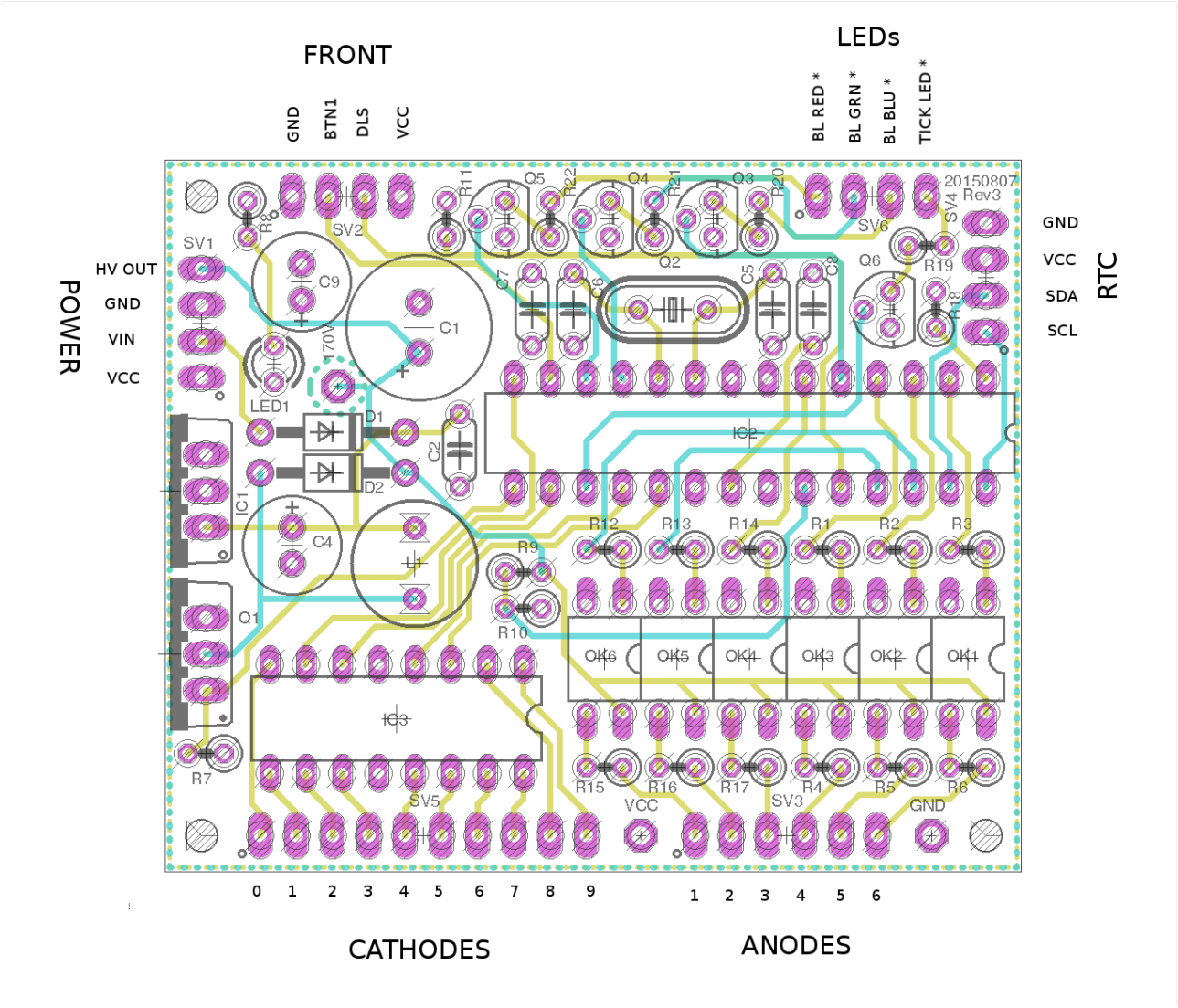
The perfect voltage for the external power supply is 7.5V or 9V DC. You can use 12V DC.

If you use more than 12V be aware that you might have to provide a heat sink for the power components and adjust the HV voltage generation. It is not advised to use more than 12V.

The absolute maximum permissible is 24V DC. Higher voltages than this will surely damage the clock.

Board layout

For reference, the board layout is as shown (viewed from the top):



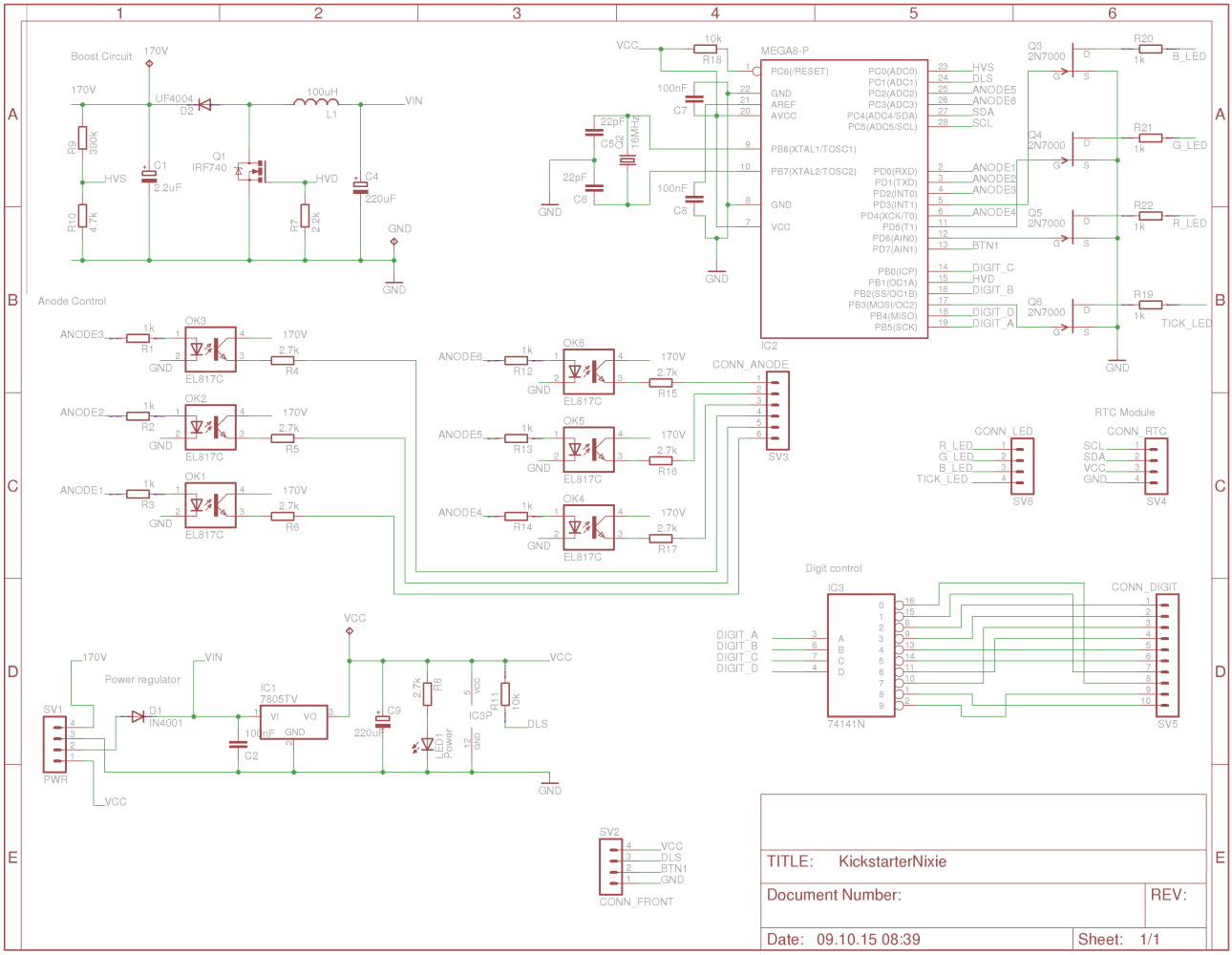
The connections are:

Connector	Description	Values
POWER	Power. External power should be applied to the board with this connector. Any DC input source is possible, from 7.5V – 12V. Higher voltages may be possible, but could cause the digits to flicker if the voltage is too high, and you might have to provide a heat sink for the the MOSFET and voltage regulator. The absolute maximum input voltage is 24V. Any higher voltage than this will damage the board within a few seconds! The input VIN is protected against the input being connected reversed. The input current ranges from 300mA to 1A depending on the size of the tubes and the number of LEDs you are driving.	

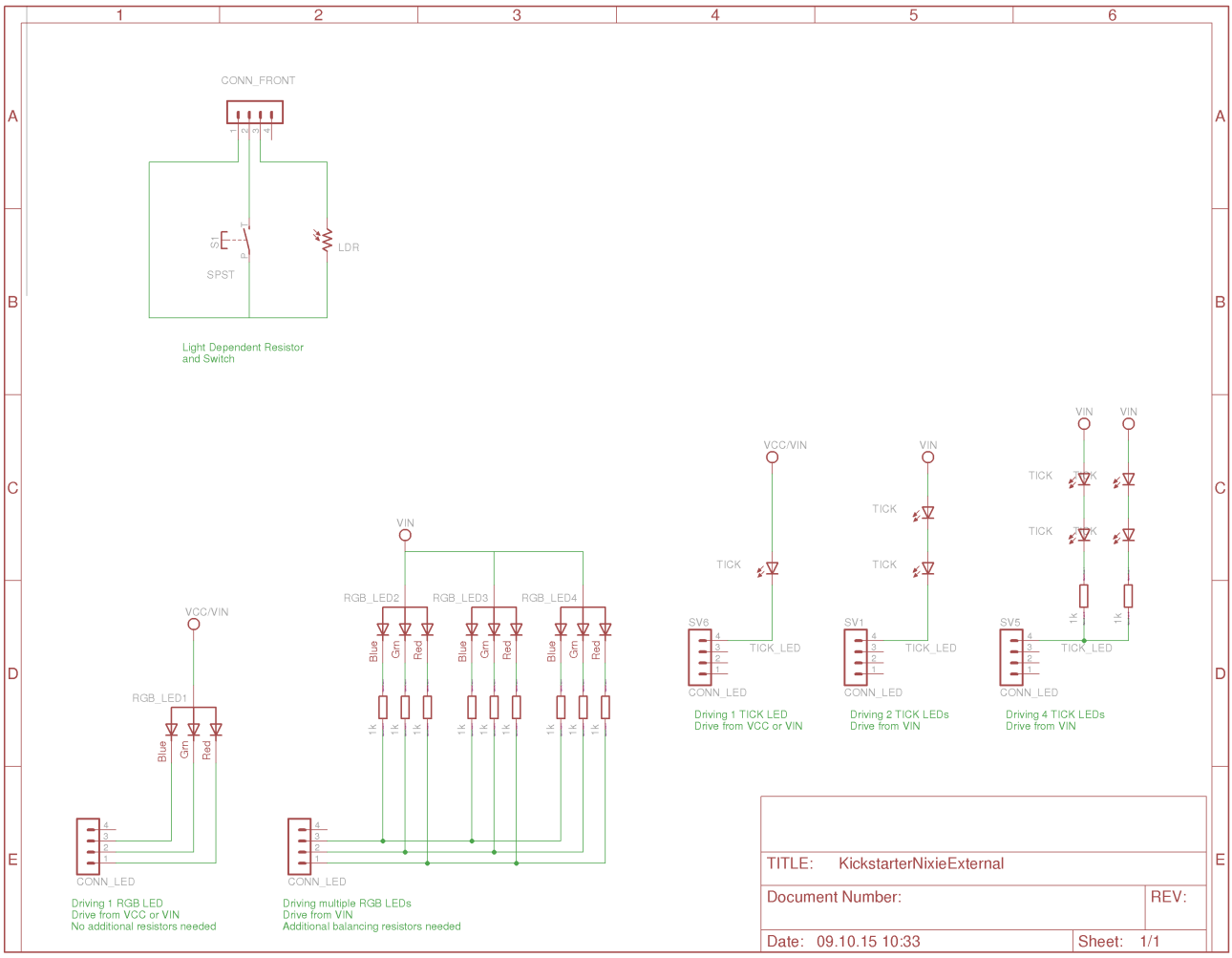
	GND: The negative side of the input supply **VIN:** The positive side of the input supply **VCC:** Output of regulated 5V **HV OUT:** Output of high voltage for driving external neons etc.
FRONT	Front Panel. These are the controls that go on the front panel: The input button and the Light Dependent Resistor to detect ambient light. **GND:** The "ground". One lead of the button and one lead of the LDR and one lead of the button are connected to this. **BTN1:** The other lead of the button is connected to this input **DLS:** "Dimming LDR Sense": The other lead of the LDR is connected to this **VCC:** Regulated 5V output to drive any LEDs or lighting. Note that you can also connect the LEDs to the VIN if you want to reduce the load of the regulator.
LEDs	The LEDs are connected to these sink (they consume current, not source it) terminals. To connect up you take the positive sides of the LEDs to either VIN or VCC and connect the negative sides of the LEDs to these terminals. **BL RED *:** PWM cathode connection for the back light RED channel. **BL GRN *:** PWM cathode connection for the back light GREEN channel. **BL BLU *:** PWM cathode connection for the back light BLUE channel. **TICK LED *:** PWM Cathode connection for the blinking "tick" LED.
RTC	The connection for the RTC (Real Time Clock) module. Connect this to the appropriately marked terminals on the RTC module.
CATHODES	The terminals to the cathodes (individual digits "0" - "9") for each tube. Terminal "0" drives the cathode "0" and so on.
ANODES	The terminals to the anodes for each tube. The allocation of anode to tube is: 1. Tens of hours 2. Hours 3. Tens of Minutes 4. Minutes 5. Tens of seconds 6. Seconds

Schematic

Below is the schematic for the clock.



And for the external components, showing how they are connected.



One side of the LDR and switch are connected to ground (pin 1, SV2).

The LEDs are driven from VCC or VIN, depending on the configuration. Here are some suggestions:

1 TICK LED:
Run the TICK LED directly from the board, either from VCC or VIN.

2 TICK LEDs:
Run the two TICK LEDs in series from VIN. You don't need a balancing resistor because the LEDs are in series.

4 TICK LEDs:
Run the TICK LEDs by putting 2 in series, and running the two series combinations in parallel. In this case you need a 1k balancing resistor in each series.

1 RGB Back Light LED:
Run the RGB LED directly from the board, either from VCC or VIN.

Multiple RGB Back Light LEDs:
Each RGB LED needs a series balancing resistor on each Red, Green and Blue cathode. I normally run 6 in this configuration.

Construction

Kit Contents:

When you unpack the kit, you should find the following contents as listed in the BOM (Bill of Materials). It is best to check the contents before you start, and notify me straight away if you are missing any components.

Please see the appendix to help you identify individual components.

Low Voltage Circuit:

Parts List:

D1	IN4001
C2	100nF
C4	220uF
IC1	7805TV
C9	220uF
R8	2.7k
LED1	LED3MM
SV1	CONN_POWER

The Low Voltage circuit is a very traditional voltage regulator using a linear regulator. It's job is to reduce the external voltage from the power adapter down to a known and stable 5V to drive the micro-controller and the 74141.

Put the parts on the board in the marked locations in the order they appear on the list.

Notes:

- See the section on “Component Identification” for help with identifying the components.
- D1 and D2 look very similar, but have different jobs to do. Be careful to get the 1N4001 and not the UF4004.
- D1 should be placed so that the white stripe on the body lines up with the white stripe on the board.
- C9 must go the right way round. The negative side is marked with a stripe. (See hint)
- The LED must go with the right polarity. The side which has the shorter lead goes nearest the diode. (See hint)
- Put IC1 so that the metal tab lines up with the white stripe on the board. The metal side faces to the *outside* of the board.

Test Step

Once all the components are on the board, hook up the power, and check that the power LED comes on.

Check also that the voltage is 5V between the “GND” test point and the “VCC” test point and at the power connector.

Trouble shooting

If the LED does not come on, turn off immediately to avoid damage to the components. Check your soldering and the polarity of the components.

If the components are in the right way, connect the power again, and check that the 7805 voltage regulator does not get hot. If it does not, measure the voltages in the low voltage circuit.

Measure the voltage at the input ("Vin") and at the cathode side of D1 (nearest the centre of the board). This should measure 0.7V less than the input voltage.

If all is well, proceed to the next step. If not, check carefully the orientation of the components and the power leads. Diode D1 protects the board from having the power connected inverted.

If the LED comes on, check for a few seconds that the 7805 does not heat up. It should stay almost cold.

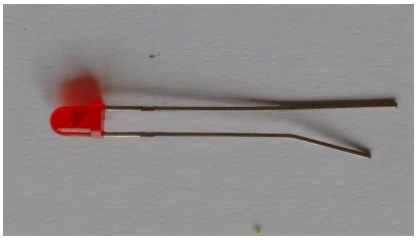
Hint: The 220 uF capacitor

The electrolytic capacitor has a stripe on it to denote the **negative** side of the capacitor. The positive side of the capacitor (which goes into the "+" on the board) is the other one!

220uF capacitor "stripe"

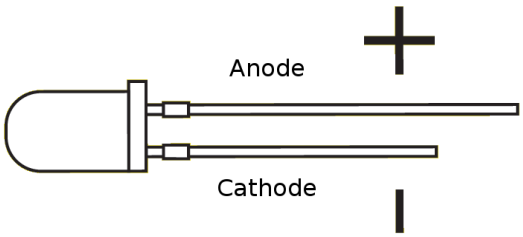
Hint: The LED orientation

The LED has one lead longer than the other, and a flat on one side. The side with the **shorter** lead (the cathode) goes into the hole on the board nearest the diode.

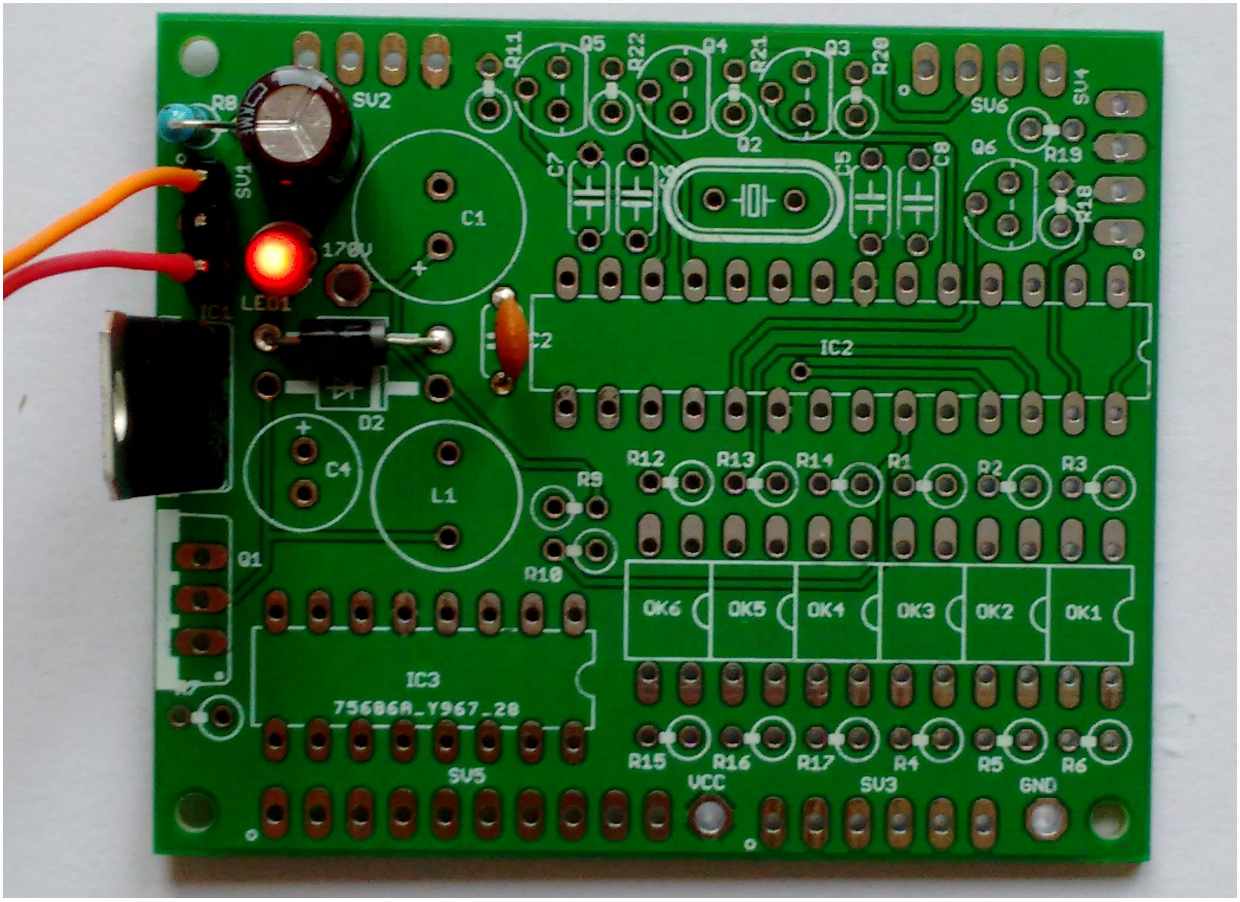


The LED

The LED should look something like this:



At the end of the low voltage circuit build, your board should look like this:



Low Voltage Circuit

High Voltage Circuit:

Parts List:

C5	22pF
C6	22pF
C1	2.2uF 450V
C7	100nF
C8	100nF
D2	UF4004
S28	SOCKET 28
Q2	16MHz
L1	100uH
R7	2.7k
Q1	IRF740
R9	390k
R10	4.7k
R18	10k
IC2	MEGA8-P

The high voltage circuit uses the micro-controller to drive the boost circuit with a high frequency square wave, and has a feedback loop in which the controller reads the voltage produced via an analogue input, and regulates the brightness of the tubes so that there is no flickering or unwanted dimming.

Notes:

- See the section on “Component Identification” for help with identifying the components.
- C4 must go the right way round. The negative side is marked with a stripe (see hint).
- Put Q1 so that the metal portion lines up with the white stripe on the board. The metal side faces to the outside of the board.
- D2 should be placed so that the white stripe on the body lines up with the white stripe on the board.
- Put the micro-controller socket in first. Make sure that the depression on the end of the socket lines up with the marking on the board. When you put the chip in, the chip should go in with the depression faces to the outside of the board.

Once all the components are on the board, hook up the power. Give your work a careful check to make sure that the orientation of the components is right. Especially check that the stripe on C1 is facing the top of the board (not near the 170V test point).

Test Step

Apply power to the board again. Listen for any stressed sounding buzzing or humming, and check that neither the 7805 nor the IRF740 get excessively hot.

Check that the power LED still lights.

Trouble shooting

If you hear any angry sounding buzzing turn the power off immediately and check the orientation of C1! The circuit should run almost silently, with only a very faint "crackling" sound.

If you can't reach the target voltage, turn off and check the polarity of your components, especially C1. If you have an oscilloscope, you can check the voltage at the gate of the MOSFET, and it should show pulses of high frequency square wave: this is the driver waveform to the HV generator, which is being turned off and on by the voltage detection, trying to achieve the target voltage (180V default).

Be careful, we are dealing with high voltages now! The voltage may be significantly higher than 170V at the moment, because the high voltage generator is powerful and the output is not loaded. Once you add a load, (by connecting the tubes), the voltage should oscillate around 170V – 190V, and might have a slight "sawtooth" appearance if you view it with an oscilloscope.

Note also that the "Power" header also has high voltage exposed on it! This is if you want to drive neons instead of LEDs for the colons. Be careful handling the board, it is easy to touch the "Power" header by mistake. If you are sure you won't be needing it, you can snap the extra pin off and populate only the bottom 3 pins on the connector.

Test Step

Check the voltage at the 170V test point. You should read a voltage in excess of 170V.

You can also test using an old neon lamp if you have one. Temporarily connect the neon lamp between the "GND" test point and the "170V" test point with an appropriate ballast resistor (turn the power off first). Turn the power on and the neon lamp should come on.

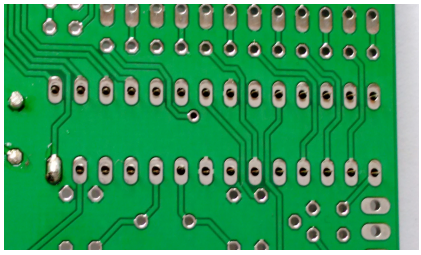
Trouble shooting

Q1 can get warm, **but should not get too hot to touch**. If it gets hot, you need to check the orientation of the components and that there are no solder bridges.

If you don't get the expected voltage reading, and instead you get around 90V -150V, please temporarily connect the LDR and re-test. Under some circumstances, the HV generator is started in the off state and the missing LDR means that it does not recover.

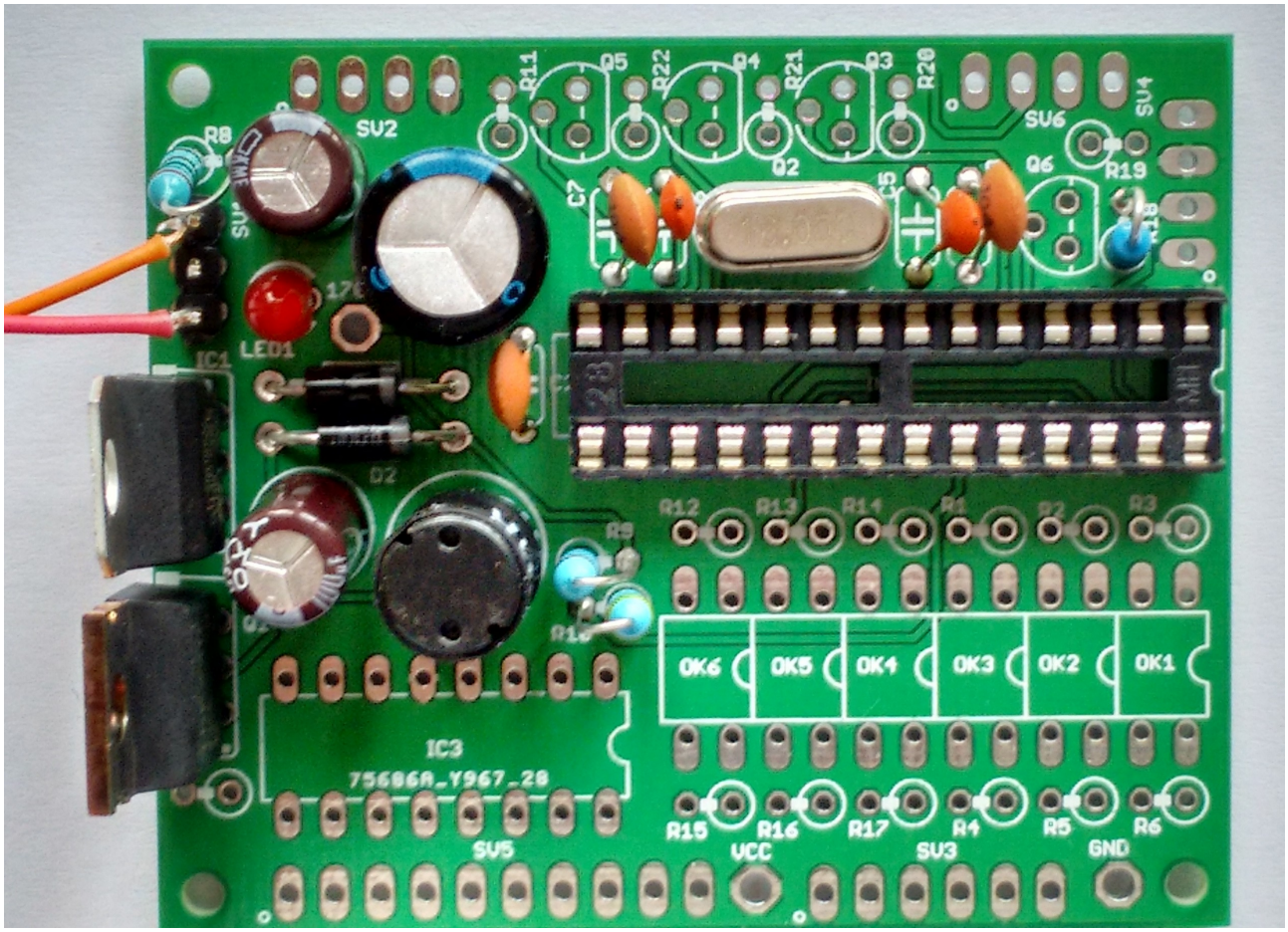
Hint: Mounting the 28 pin socket

Mounting the 28 pin socket can be a little tricky. A good trick is to fix it in place with a small piece of tape, and the solder one leg in place. You can hold the socket firm while you "wet" the solder again, which will hold the socket firmly enough to solder the remaining pins. One leg is usually enough to hold the socket in place while you solder the others.



Mounting 28 pin socket

At the end of the high voltage circuit build, your board should look like this:



High Voltage Circuit

“TICK LED” Circuit:

Parts List:

RTC	RTC (see note)
SV4	CONN_RTC (see note)
R19	1k
Q6	2N7000
TICK LED	LED 5mm
SV6	CONN_LED
SV2	CONN_FRONT
R11	10k

This step will check that the Micro-controller can talk to the RTC module, and that the time counting is working properly. The flashing rhythm of the “tick” LED comes from the RTC module, and we want to check that we are able to communicate with the RTC module..

Notes:

- If you want to have two LEDs for the “tick” circuit, you can place these in series, and power them from the unregulated VIN voltage.
- Q6 should be orientated with the flat side as shown on the board. Some FETs come with the leads in a row rather than in a triangle. If this is the case, bend the middle lead slightly so that it fits the holes in the board (see hint).
- The RTC module has two sets of contacts on it. You can use either the side with the pins on it or wire up the other side with flying wires. If you use the side with pins, you should carefully remove the two unused pins (see hint). If you use the contacts on the module, you should leave CONN_RTC off the board.
- If you receive the connector header as a single strip, break off 4 pins for SV6 and 4 pins for SV2.
- The LED must go with the right polarity. The “-” side has a flat on it, and has the shorter lead (see hint), and must be connected to pin 4 of SV6.
- R11 is needed to bias the LDR ambient light detection circuit, to make sure that the LED lights up reliably.

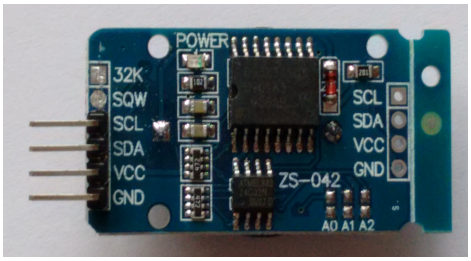
The LED should be wired up with the longer lead to pin 4 of the CONN_FRONT (SV2) connector and the shorter lead to pin 4 of the CONN_LED (SV6) connector. (Pin 1 has a little “o” beside it on each connector on the board).

Test Step

Once you have populated the components, power on. The LED on the RTC module should come on, and the “TICK” LED should flash on and off slowly (on for one second, off for one second). It might take a second or two to come on, but after that should “pulse” on and off.

Hint: Trimming the extra pins on the RTC module

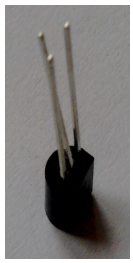
> ONLY if you want to mount the RTC module directly onto the main board (you can also do it via flying leads), trim off the pins “32K” and “SQW” using a pair of precision side cutters.
>
> If you want to mount using flying leads, you can skip this step and use the four holes on the other side of the board.



RTC Module with pins removed

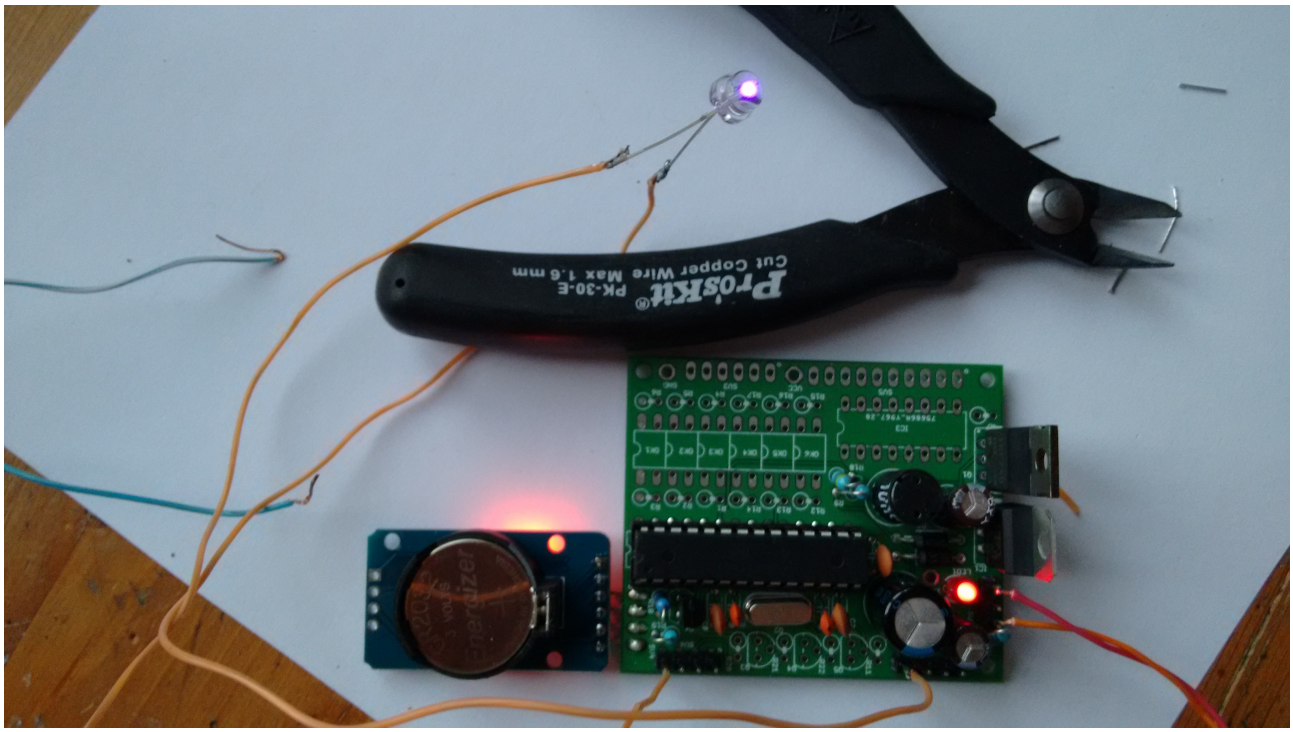
Hint: 2N7000 mounting

> To mount the 2N7000 FET, bend the middle lead back slightly. It will then fit in the PCB without problems.



2N7000

After you have wired everything up, it should look like this:



Note that here I have put the RTC module directly onto the main board. The battery goes in the RTC module with the back (with the writing on it) upwards.

Anode Control Circuit:

Parts List:

S24	SOCKET 24
OK1	EL817
OK2	EL817
OK3	EL817
OK4	EL817
OK5	EL817
OK6	EL817
R1	1k
R2	1k
R3	1k
R12	1k
R13	1k
R14	1k
R4	2.7k
R5	2.7k
R6	2.7k
R15	2.7k
R16	2.7k
R17	2.7k
SV3	CONN_ANODE

This circuit controls passing the HV to the anodes of the tubes. The micro-controller multiplexes the anodes by turning each of them on it turn for a very short period of time. The software controls the rate of the multiplexing and the order in which the anodes are activated.

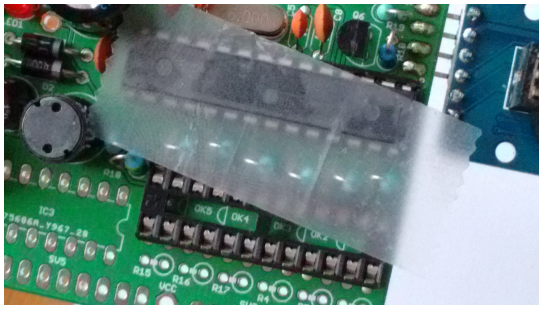
Notes:

- The Opto-Isolators fit into the 24 pin socket snugly. Be careful to put them in the right way round. The dot denotes pin 1 and should be on the side closest to the micro-controller. All 6 should fit perfectly into the 24 pin socket.
- The Opto-Isolators are socketed because they are sensitive to heat and are easily destroyed if you apply too much heat to them. Putting them in a socket means that we don't run the risk of destroying them while soldering.
- If you receive the connector header as a single strip, break off 6 pins for SV3.

Hint: Putting the resistors in

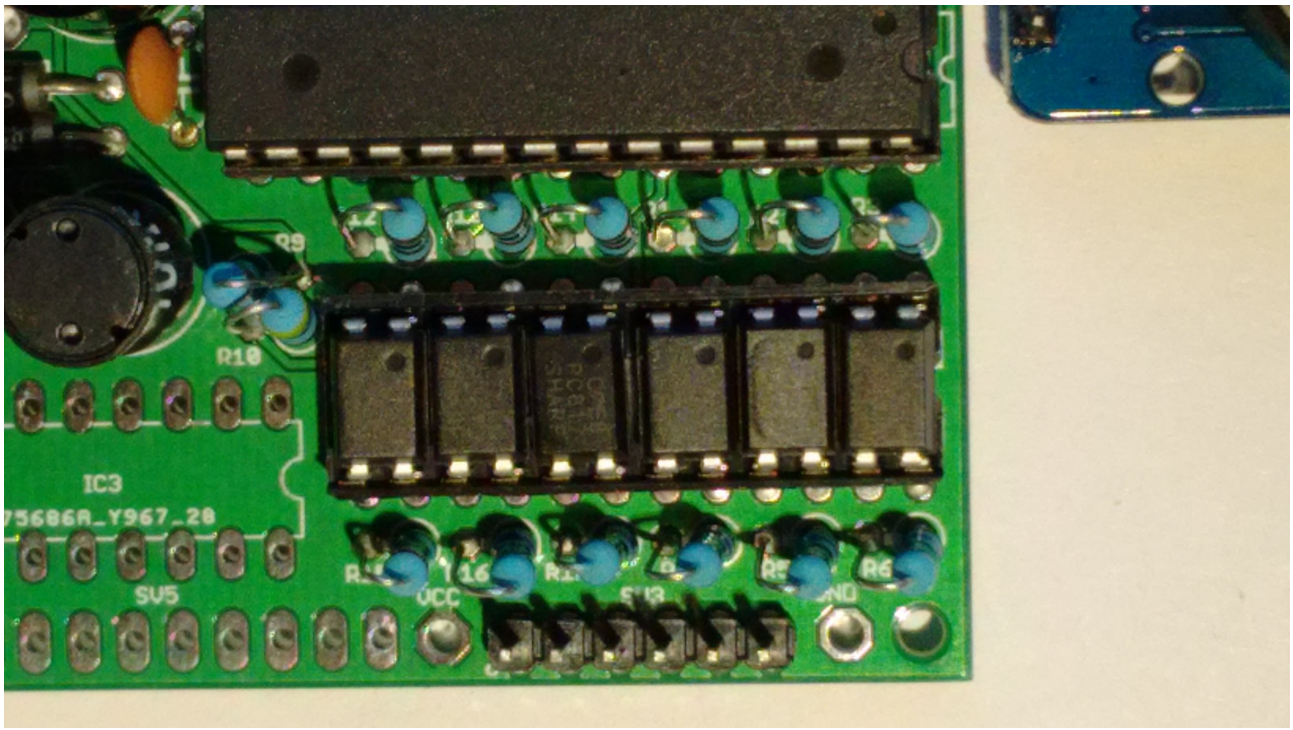
A trick that can speed assembly up is to use a piece of normal sticky tape to hold things in place while you solder them. This makes is easier to solder and gives a better result.

Place the components, and then temporarily tape them into place.



Using tape to hold resistors in place

After you have installed the Anode controls, that part of the board should look this:



Cathode Control Circuit:

Parts List:

IC3	74141N/K155
S16	SOCKET 16
SV5	CONN_DIGIT

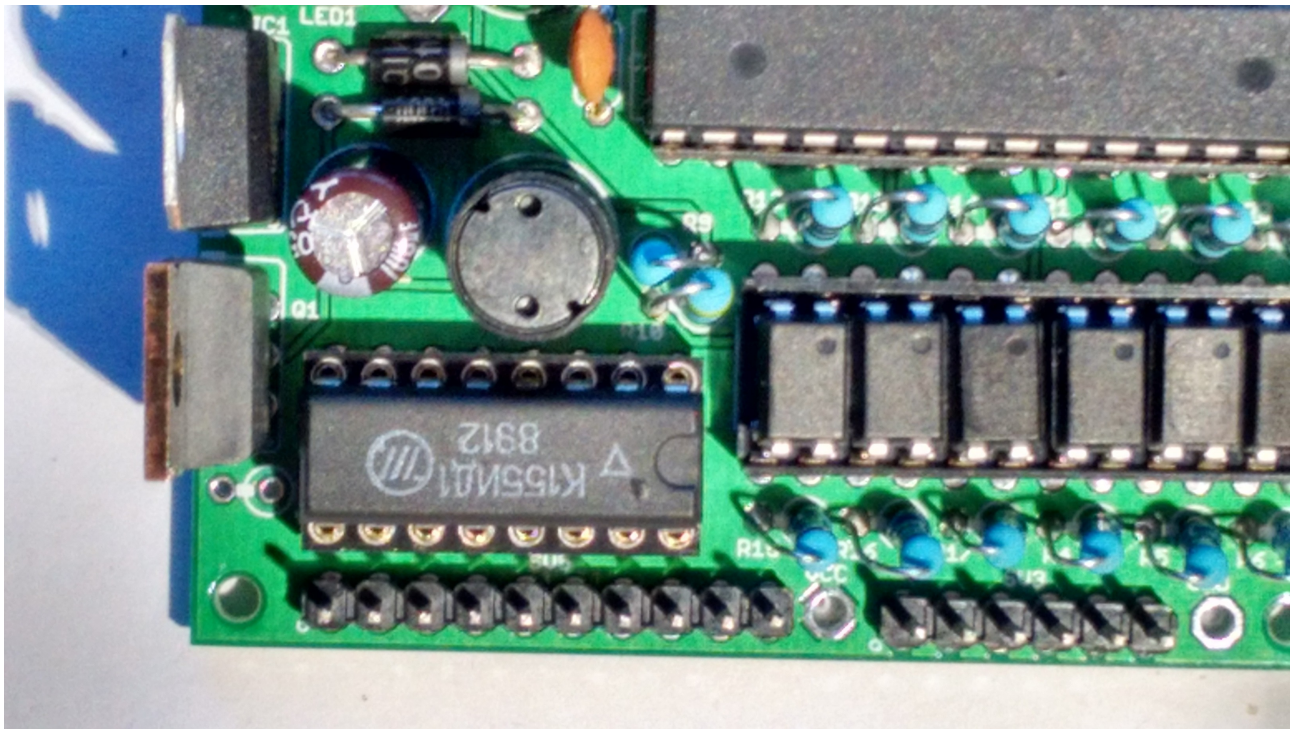
This part of the circuit controls which cathode will be lit. Each time the digit to be displayed, the correct cathodes have to be set.

Notes:

- Instead of the 74141, you might have the Russian equivalent “K155”.
- Be careful to orient the 74141 correctly
- If you receive the connector header as a single strip, break off 10 pins for SV4.

Place the 16 pin socket and the connector, and then put the cathode driver on the board.

After you have done this, that part of the board should look like this:



LEDs and front panel

Parts List:

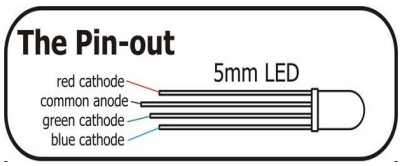
R20	1k (*)
R21	1k (*)
R22	1k (*)
Q3	2N7000
Q4	2N7000
Q5	2N7000
LDR	LDR
S1	SWITCH
LED RGB	LED RGB Common anode

These are the final parts of the clock apart from the tubes, and are intended as the elements which the user sees and touches.

This is the last step of the main board build.

Notes:

- The FETs should be orientated with the flat side as shown on the board. Some FETs come with the leds in a row rather than in a triange. If this is the case, bend the middle lead slightly so that it fits the holes in the board (see hint).
- If you want to run more than one back light LED from the board, see the note below.
- The LDR is connected between pin 1 (GND) and pin3 (LDS) of SV2.
- The switch is connected between pin 1 (GND) and pin2 (BTN1) of SV2.
- The RGB LED has a flat on one side and one lead longer than the rest. The common anode is the longest pin. The Red cathode is next to the flat on the case. The green is next to the anode, and the blue is on the side farthest from the flat.
- The RGB LED anode is connected to pin 4 (VCC) of SV2. Red is connected to pin 1 of SV6, green to pin 2 of SV6 and blue to pin 3 of SV6.



(*) You can run more than one back light LED for each R,G or B channel. If you want to do this, replace this resistor with a simple PCB link, and put a 1k resistor in series with each LED cathode instead. You can run between 4 and 6 LEDs off the driver depending on the type and the supply (you can choose the regulated 5V or the unregulated VIN). The total current for each channel should not exceed 200mA.

Often, when running from VIN, you can leave the 1K resistor on the board and additionally place a 1K resistor in series with each LED cathode.

Likewise, you can run two TICK LEDs in series from VIN with the 1K resistor on the board.

Calculate the current consumption of the LEDs

If you want to drive multiple LEDs or want to run the LEDs from VIN, please check the current consumption. It is very easy.

To calculate the current drawn, you can measure the forward drop V_{FWD} across the LED when it is on, and

use the following formula to calculate the current:

$$I_{LED} = V_{CC} - V_{FWD} / 1k$$

For example, with a V_{FWD} of 2.2V, the current is:

$$I_{LED} = 5 – 2.2 / 1k = 2.8mA$$

In this case, you can safely run 6 LEDs off the channel.

Front Panel components

When all the components are installed, you are finished with the board.

The switch connects to ground when closed. It uses the internal pull-up resistor provided by the Atmega on the input pin to pull the input to VCC when the switch is not closed.

The switch is de-bounced in software, so practically any switch you want to use is suitable. A simple switch is provided in the kit, but you might want to substitute this switch with one that suits you case.

The LDR should be mounted in such a way that the flat face of the LDR is exposed to the ambient light. This will allow it to detect the ambient light and adjust the brightness for it.

Connecting the tubes

When all the components are installed, you are now ready to install the tubes. Either you can wire then by hand or you have a board to put them on. I prefer hand wiring, because I think it has a more “retro” feel.

The anodes are arranged like this:

Anode “1”	Hours 10s
Anode “2”	Hours
Anode “3”	Minutes 10s
Anode “4”	Minutes
Anode “5”	Seconds 10s
Anode “6”	Seconds

Anode “1” is the one next to the tiny “o” printed on the board next to the connector.

The cathodes are arranged like this:

Cathode “0”	Digit 0
Cathode “1”	Digit 1
Cathode “2”	Digit 2
Cathode “3”	Digit 3
Cathode “4”	Digit 4
Cathode “5”	Digit 5
Cathode “6”	Digit 6
Cathode “7”	Digit 7
Cathode “8”	Digit 8
Cathode “9”	Digit 9

Cathode “0” is next to the tiny “o” printed on the board next to the connector.

Side note: There are some tricks in the software to make the wiring and the PCB easy and logical. We use a translation table in the software, and cross some of the standard channels to make the PCB more logical. You can also see this on the “digit control” section of the schematic. This means that we are not using the 74141 “0” output to drive digit “0”, but instead we are using digit “2” of the 74141 to drive digit “0”.

In the code (available on GitHub), we see this:

```
// Used for special mappings of the 74141 -> digit (wiring aid)
// allows the board wiring to be much simpler<
int decodeDigit[16] = {2,3,7,6,4,5,1,0,9,8,10,10,10,10,10,10};
```

When we come in with a “0”, we decode this to “2” (the 0th element of the array), and in fact, it is the “2” output that is activated, but the wiring brings the “2” output to the “0” connection.

The cathodes to the tubes (the digits for each tube) need to be wired in parallel, “daisy chaining” them, so that the run to the same digit of each tube.

The anodes run exactly one tube each.

Tube wiring

If you bought a kit without a display board, there is the task of wiring the tubes to be done. It can take a long time, but if you do it carefully, it can give a very beautiful “retro” feel.

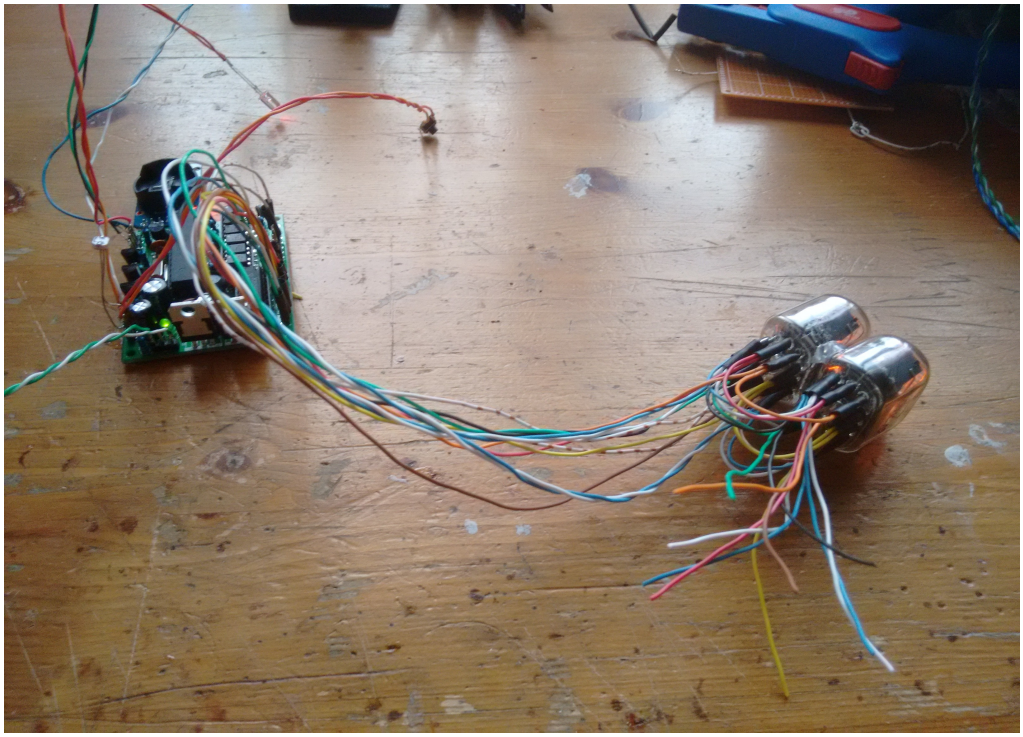
There are a number of small tricks to make the task easier and the result better:

- Plan how long you want the lead to the board to be and how far apart the groups of digits “hours”, “minutes” and “seconds” should be.
- Temporarily either glue, tape or bind together the groups of digits while you are working on them. Later you can choose to substitute the temporary binding, or keep it if you wish.
- If you use heat shrink, do not shrink it until the end of the wiring. The reason for this is that we will complete the looming at the end, and will need to disconnect the board from the loom to tidy it up. Also for the identification of errors, it is useful to be able to switch or disconnect connections.
- Pre-cut the wires you are going to use, use different colors for each cathode or anode if possible. Keep the same color for each cathode as you proceed through the wiring. Make sure that all the wires for each task are the same length. The main wire tasks are:
    - Flying cathode connections (recommended 30cm):
        - 10 x flying cathodes from the board to the tubes
        - 6 x flying anodes from the board to the tubes
    - Intra group cathode connections (recommended 7cm):
        - 3 x 10 x cathodes
    - Inter group cathode connections (recommended 7cm):
        - 2 x 10 x cathodes
    - Flying anode connections (recommended 40cm):
        - 6 x flying anodes from the board to the tubes
- Wire anode 6 and anode 5 to the first group (“seconds”) from the board to the tube. Always make the flying lead connect to tube 6 first, then tube 5. This means our connection loom will come out at tube 6.
- Wire cathode “0” and cathode “1” from the board to tube 6 and daisy chain to tube 5. Prepare the daisy chain connection to the next group but **do not strip** the wire to the next group yet.

- You should have a result like this:

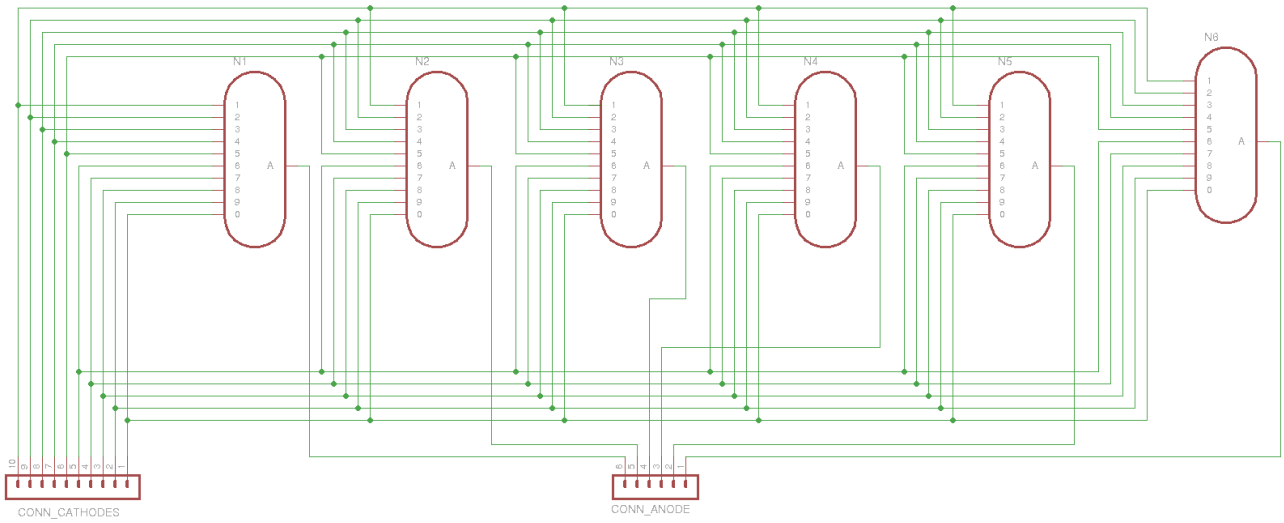
- Turn on the clock and check that you can clearly see the digits “0” and then “1” light up in sequence on the seconds tube every 10 seconds. Don't worry if there is “ghosting” on other digits at the moment – this will resolve itself as you connect more tubes and digits. (There are still a lot of floating connections at this point in the build and we are not loading the HV generator propery).
- Proceed to the other cathodes in turn, each time leaving the unstripped lead to the next group hanging.
- Try to pick an order you connect the tube cathodes in, and stick to it. This will give the wiring a “regular” feel. If there are any tangles or crossovers in the wiring, resolve them before soldering the wire in place.

- After you connected all the wires of the seconds group, you should have a result that looks like this:

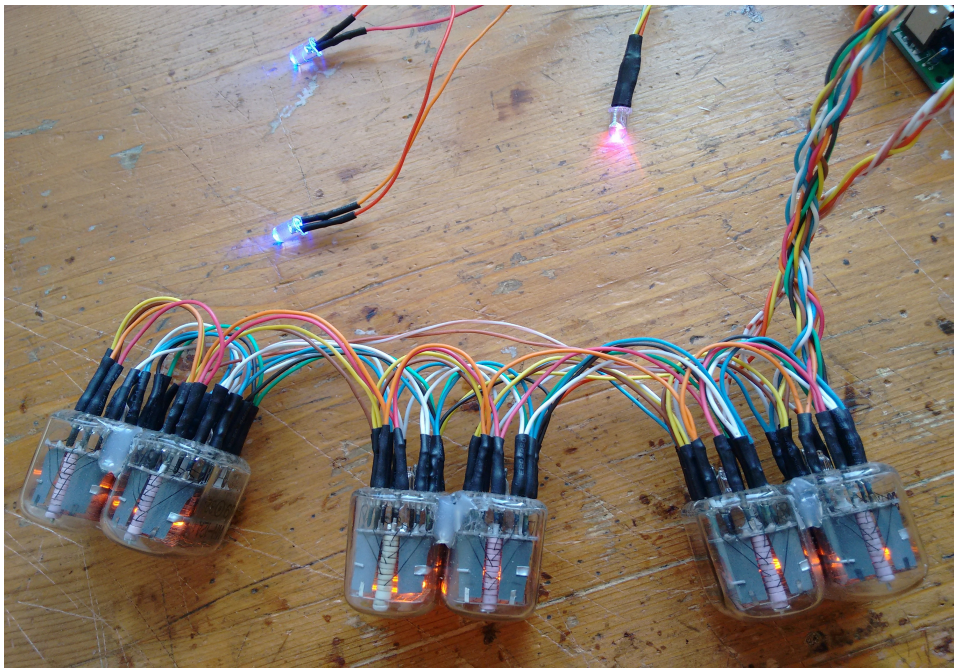


- Turn the clock on, and you should now see the seconds counting correctly.
- Complete the other groups in the same way, keeping the cathode connection colors and the order in which you connect them the same.
- At the end of the connection process, we want to “loom” the wiring. This involves binding and/or plaiting the wires to make them regular. For this you will need to disconnect the wires from the board. Make a note of the colors of each of the cathodes and anodes, because we will need to reconnect them in the same way.
- I usually plait the 6 anodes together in 3 groups two wires each, and the 10 cathodes in 5 groups of two wires. 3 plaiting and 5 plaiting can be found on YouTube. It is optional to plait the wires and simply binding them gives a good result as well.

The wiring for the tubes is this:



Here is a picture of a plaited loom in action. This particular version of the clock has two blue “tick” LEDs in series and three RGB LEDs (one for each digit group):

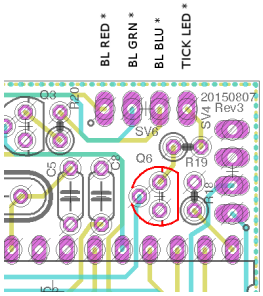


Hacks and alternatives

There are a number of options which can be built into the board easily.

Using Neons instead of LEDs for the “Tick” LED.

This is a very simple modification. Replace the 2N7777 (Q6) with an MPSA42. The MPSA42 transistor has a compatible pin out to the FET (drain = collector, gate = base, source = emitter), but can withstand 300V. After doing this, you can connect one or more neon lamps instead of the LED.



This gives a more “retro” feel to the result.

For each neon, place a 56-100k resistor in series, and drive from the HV output on the power connector on the board. Here is an example with a 56k resistor and two INS-1 neons:

Driving 2 neons from the “Tick” circuit

Troubleshooting

If not everything goes as you expect, please refer to the test steps during the construction and the associated troubleshooting tips. If that does not cover the problem you have, please see below. If you still can't find the answer, contact us!

Trouble shooting

The display brightness is not constant, and appears to “pulse” rapidly.

This is a symptom that the High Voltage generator or the external power supply is overloaded.

First perform a factory reset to make sure that no strange values have been left in the EEPROM.

Next, check the value of the **PWM On Time** configuration. Try increasing this until the brightness is constant, but be careful not to set the value too high. The longer the On Time, the more the MOSFET has to conduct current, and this will cause it to heat up. A good value for small tubes is 120-150, larger tubes may require 150-200.

Trouble shooting

The display is too dim.

Check if the auto-dimming is working. If the display does not change in low or high ambient light, your LDR does not appear to be working. Check the connections to the LDR.

If the LDR is correct, perform a factory reset to make sure that no strange values have been left in the EEPROM.

Check the LDR reading by pressing the button three times in quick succession. You should see a value between “01 00 00” and “09 99 00”. Changing the light conditions should change this value. It is normal that the value is not stable when it is in the middle of the range. We read the LDR many times a second, and it is unusual that two readings are identical.

Trouble shooting

The display does not come on, but I do have a high voltage.

Try pressing the button. If the display comes on, you probably have display blanking mode set. Check the configuration.

Check the orientation of the opto-couplers.

Check the LDR connection. In some cases, the dimming algorithm does not start up as expected when no LDR is present. Shine a bright light on the LDR.

In some cases, a factory reset can help.

Component Identification

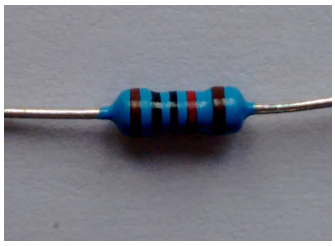
We can't always guarantee to get exactly the the same components. Where we have alternatives, they are listed separately under the same heading.

10k resistor

Alternative 1

The color code for the 10k resistor is:

BROWN = 1
BLACK = 0
BLACK = 0
RED = 2 (2 zeros in this case)
BROWN = 1 (1% Tolerance)
= 1 0 0 0 0 with 1% tolerance

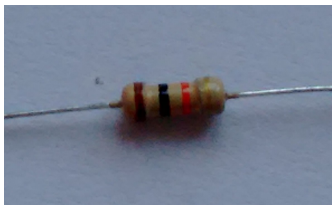


10k resistor

Alternative 2

The color code for the 10k resistor is:

BROWN = 1
BLACK = 0
ORANGE = 3 (3 zeros in this case)
GOLD = 5% Tolerance
= 1 0 0 0 0 with 5% tolerance



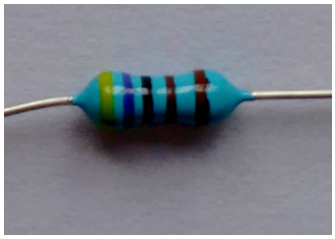
10k resistor

4.7k resistor

Alternative 1

The color code for the 4.7k resistor is:

YELLOW = 4
VIOLET = 7
BLACK = 0
BROWN = 1 (1 zero in this case)
BROWN = 1 (1% Tolerance)
= 4 7 0 0 with 1% tolerance

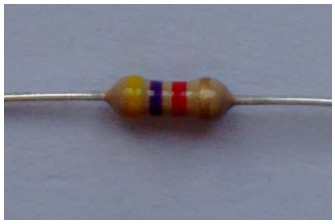


4.7k resistor

Alternative 2

The color code for the 4.7k resistor is:

YELLOW = 4
VIOLET = 7
RED = 2 (2 zeros in this case)
GOLD = 5% Tolerance
= 4 7 0 0 with 5% tolerance



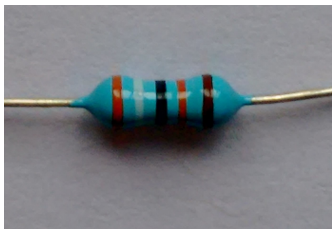
4.7k resistor

390k resistor

Alternative 1

The color code for the 390k resistor is:

ORANGE = 3
WHITE = 9
BLACK = 0
ORANGE = 3 (3 zeros in this case)
BROWN = 1 (1% Tolerance)
= 3 9 0 0 0 0 with 1% tolerance

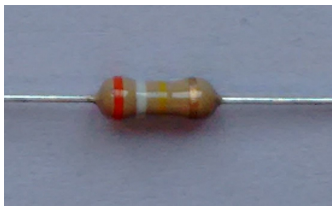


390k resistor

Alternative 2

The color code for the 390k resistor is:

ORANGE = 3
WHITE = 9
YELLOW = 4 (4 zeros in this case)
GOLD = 5% Tolerance
= 3 9 0 0 0 0 with 5% tolerance



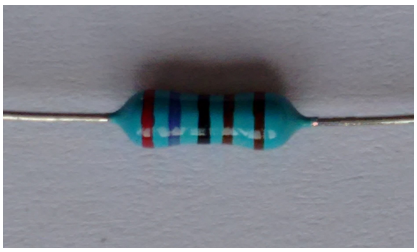
390k resistor

2.7k resistor

Alternative 1

The color code for the 2.7k resistor is:

RED = 2
VIOLET = 7
BLACK = 0
BROWN = 1 (1 zero in this case)
BROWN = 1 (1% Tolerance)
= 2 7 0 0 with 1% tolerance

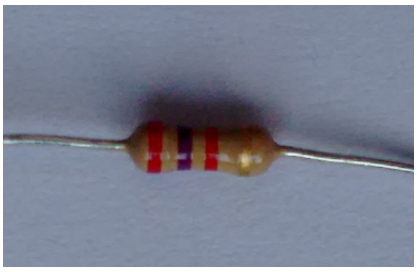


2.7k resistor

Alternative 2

The color code for the 2.7k resistor is:

RED = 2
VIOLET = 7
RED = 2 (2 zeros in this case)
GOLD = 5% Tolerance
= 2 7 0 0 with 5% tolerance



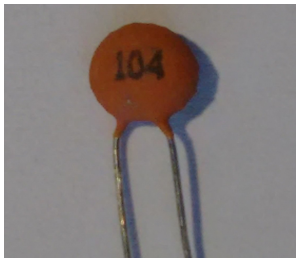
2.7k resistor

100nF capacitor

The coding on the 100nF capactor is “104”. It does not matter which way round it goes.

This is decoded as:

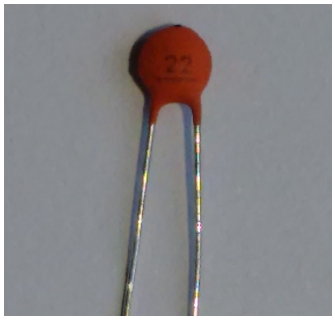
= “1” then a “0” and then 4 more zeros
= 100000 pF
= 100 nF (1 nF = 1000 pF)



100nF capacitor

22pF capacitor

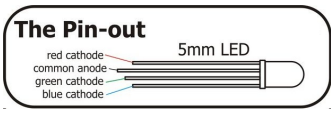
The coding on the 22pF capactor is simply “22”. It does not matter which way round it goes.



22pF capacitor

RGB LED

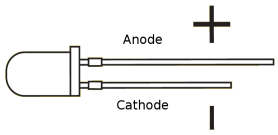
The RGB LED has one pin longer than the rest. This longer pin is the common anode.



RGB LED

LED

The LED has one pin longer than the other. The long pin is the anode, the short pin the cathode.



LED

Revisions:

V0007a: 20May2015: Change C4 and C9 to 220uF
V0008a: 06Jun2015: Add HV target voltage setting.
V0008b: 09Jun2015: Clarify input voltage requirements.
V0008c: 17Jun2015: Correct LED orientation.
V0009a: 30Aug2015: Updated for board Rev2
V0010a: 04Sep2015: Updated for board Rev3
V0010b: 14Sep2015: Added options and more troubleshooting tips
V0010c: 01Oct2015: Change GitHub software versioning
V0010d: 23Oct2015: Move C4 into LV section, correct 1uF to 2.2uF in HV section